A Study of Barriers to Women in Undergraduate Computer Science

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Abstract

Worldwide, there is a significant discrepancy between the numbers of male and female graduates from computer science programs. SUNY Geneseo offers no exception. The literature cites a number of plausible explanations for the problem, but no definitive answers. We conducted a study to determine why few women complete our own computer science major. Our major finding is that (at least on our campus) the problem is not actually one of retention. Few women—even those in the introductory computer science courses—actually plan to major in computer science to begin with. Although some barriers suggested in the literature do operate within the major, they seem much less significant than the low entry rates. Retention of women once they enter the major is important, but it is secondary to getting women into the major initially. This suggests that the most effective solutions will be those that concentrate not on retention but on recruitment (including outreach to secondary schools).

1. Introduction

At SUNY Geneseo, the members of the Computer Science Department informally observed that: although roughly 2/3's of the college's students are women and roughly 1/2 of all students in introductory computer science courses are women, less than 1/4 of the students who graduate with degrees in computer science are women. This apparent attrition of women in our computer science program would be consistent with national patterns [3]. Although many barriers to women in the academic pipeline have been suggested in the literature as explanations for these patterns [1, 2, 3, 4, 5, 7], there are good reasons to expect that these barriers should be lower, or even totally absent at Geneseo:

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- Four out of 9 faculty in the Department are women. Therefore, female role models and mentors are more available than at many other schools.
- The campus is located in a safe rural setting. This should reduce safety concerns when working late in laboratories and traveling home after hours.
- Our curriculum emphasizes mathematics and experimentation in addition to traditional programming in computer science.
- Finally, we encourage students to work together rather than alone. Our students should thus realize that computer science is not just a discipline of solitary hackers.

In spite of any such expectations, women at Geneseo clearly don't receive computer science degrees at a rate proportional to their numbers in the campus population—not even in proportion to their presence in the introductory course. Therefore, we decided to replace our informal sense that there was a problem with a more rigorous search for the causes.

2. Our Study

We studied the problem in two stages: First, we ran a series of focus groups, attempting to identify specific barriers to women computer science students that operate at Geneseo. Second, we used the results from the focus groups to help develop a directed questionnaire to study the most likely barriers more scientifically.

The focus groups generated little consensus among participants about specific barriers to women. In addition, they were too poorly attended to be statistically valid. We were, however, able to base a questionnaire on a combination of the most frequent comments from the focus groups and on hypotheses from the literature that seemed most plausible locally. The initial surveys suggested six general hypothetical barriers we wanted to test via the questionnaire:

1. General social pressures (e.g., attitudes of friends and family) discourage women from pursuing computer science.

2. Women face more crises of self–confidence over their performance in computer science than men do.

3. Women don't have as much chance as men to contribute ideas in classes, and their contributions are under–valued when they are made.

4. Women believe that computer science is too dominated by men.

5. Women believe math is an important part of computer science, yet suffer more than men from math anxiety.

6. Women feel more strongly than men do that they want to raise a family, but that a career in computer science is incompatible with this goal.

The questionnaire covered the above areas along with general background information (course the student was taking, gender, intended major, etc.). We did not ask for names or ID numbers. We administered the questionnaire to all sections of introductory computer science courses at the end of the spring semester of 1995 (year 1). To check the repeatability of our results, we gave the same questionnaire to a follow up group of introductory computer science sections at the end of the spring semester of 1996 (year 2). Because of the smaller sample (161 students as opposed to 297) and the fact that some follow up respondents may also have responded to the original survey, we used the follow up data solely as a "sanity check" on the initial results. We did not pool the data or use follow up data to support new conclusions, but merely checked for inconsistencies. The complete questionnaire is available at:

http://www.cs.geneseo.edu/projects/3-Fold/survey.html.

3. Results

In all, 297 students—133 women and 164 men—responded to the year 1 questionnaire. The questionnaire included multiple questions testing each of our general hypotheses. For each proposed barrier, we identified specific null and alternative hypotheses related to the expected answers for men and women. For each general hypothesis, we therefore presented several questionnaire questions, with mean answers and significance test results (usually t–tests) appropriate to the null and alternative hypotheses for those questions. We used a significance level of $p \leq 0.05$ throughout. We address each hypothesis separately.

3.0. Student Background

We collected background data for classification purposes. We were obviously aware that women do not enroll in computer science courses at the same rates as do their male classmates (less than 50% are women in spite of a student body with 67% females). However, we initially assumed that among students who actually enrolled in introductory computing classes, the percentage who were majoring in computer science would be about the same for women and men. However, this is not the case. The number of men majoring in computer science was 37 (22.6% of the male respondents) but only 6 women (4.5% of female respondents) were computer science majors. Although our alternative hypothesis was that women major in computer science at a lower rate than men do, we had not expected the difference to be nearly so large. Interestingly, men and women minor in computer science at statistically equal rates: 43 men (26.2%) compared to 32 women (24%).

Women in our survey also had substantially less pre–college computing experience than did men. Asked to measure pre–college experience on a scale from 1 to 7, women's mean response was 2.54, men's 3.38; the difference is significant with $p = 0.001$.

The follow–up survey supported the above results in all respects.

3.1. Impact of Social Pressure

To address hypothesis 1—that simple social pressures discourage women from pursuing computer science—we asked respondents to agree or disagree with the following statements (answered on a 7 point Likert scale, with 1 defined as "Very Strongly Disagree", 4 as "Indifferent", and 7 as "Very Strongly Agree"):

"I would approve if a male friend said he was looking for a job in computing".
Women's mean = 5.59 Combined mean = 5.67

"I would approve if a female friend said she was looking for a job in computing".
Women's mean = 5.78 Combined mean = 5.62

"My friends would approve if I chose a career in computing".
Women's mean = 5.54 Men's mean = 5.38

"My parents would approve if I chose a career in computing".
Women's mean = 5.67 Men's mean = 5.67

None of these results suggest that there are particularly strong social pressures against women entering the field. We analyzed the answers given by women to the first two questions to see if women themselves believe that computer science was more suitable for one gender than the other. We also compared the answers given by men and women to see if the groups differed in their answers. We found no statistically significant evidence to reject the null (no difference) hypotheses (for the first, $p = 0.221$; for the second $p = 0.636$). Similarly, we cannot reject the null hypotheses that with equal likelihood male and female students believe friends ($p = 0.251$) and parents ($p = 0.992$) approve of their seeking computing careers. Thus, we found no evidence of peer, parental, or personal perceptions that computer science

is a career inappropriate for women.

The follow up questionnaire supported these results.

3.2. Relative Self-Confidence

To determine if men and women are equally comfortable in class debate, we asked how strongly respondents agree or disagree with the following statements (answered on the same scale as the questions about social pressure):

"I feel good about my performance in this course".
Women's mean = 4.73 Men's mean = 4.85

"Overall, I do better in the my classes than most of my classmates".
Women's mean = 4.22 Men's mean = 4.26

"I do better in this class grade-wise than most of my classmates".
Women's mean = 3.90 Men's mean = 4.18

"I am comfortable debating with my classmates in class discussions in every class in which such debates arise".
Women's mean = 4.07 Men's mean = 4.53

We conclude here that women are indeed less comfortable in our class situations. That is, the null hypothesis, that men and women are equally comfortable in class debate, is rejected with $p = 0.008$. Our alternative hypothesis, that women are less comfortable in class debates than men, is supported.

We also asked two questions about willingness to express one's own opinions in class (answered on a 7 point Likert scale, with 1 defined as "Never" and 7 as "Always"):

"When the professor makes a mistake in class, I correct him/her".
Women's mean = 2.91 Men's mean = 3.40

"When I know the answer to a question in class, I raise my hand to answer it".
Women's mean = 3.57 Men's mean = 3.62

On the first question, but not the second, we again found a difference between the genders: the null hypothesis, that men and women are equally likely to correct a professor, is rejected with $p = 0.004$; our alternative hypothesis, that women are less likely to correct a professor, is supported. But on the second question we found no evidence that women were less willing to speak up in class.

The follow up questionnaire produced very similar means, and generally similar tests of significance. Surprisingly, the follow up data for the question about comfort in class debates failed to reject the null hypothesis (women's mean = 4.05, men's = 4.30, $p = 0.251$). The only other difference was that the follow up data marginally failed to reject the null hypothesis for "when the professor makes a mistake in class, I correct him/her" ($p = 0.076$).

In summary, we did find evidence for the hypothesis that women in our introductory courses feel less self-confident than do men. However, we believe that the impact of this difference may be small since (a) both men and women answered questions toward the "confident" end of the scale, and (b) the evidence was not uniform across the questions (in the initial survey, one out of the four showed no evidence; in the follow up, 2 of the 4 showed none).

3.3. Are Women's Contributions Under-Valued

We asked 3 questions to measure differences in the perceived value of men's and women's contributions in the classroom. In each case answers are on a 7 point Likert scale (1 defined as "Only Men's Contributions are Valued", 4 as "Men's and Women's Contributions are Equally Valued", and 7 as "Only Women's Contributions are Valued"):

"Rate the relative value your classmates attach to men's and women's contributions in this class".
Women's mean = 4.00

"Rate the relative value the professor attaches to men's and women's contributions in this class".
Women's mean = 3.88

We found little evidence of this problem. In neither case can we reject the null hypothesis (that the opinions of men and women are equally valued) ($p = 1.000$, and $p = 0.063$, respectively).

We also asked how strongly respondents agree or disagree with the statement:

"My professor gives me a fair chance to participate in class".
Women's mean = 5.21 Men's mean = 5.35

And we cannot reject the null hypothesis that women and men feel equally fairly treated ($p = 0.336$).

The follow up questionnaire did find a difference for one of the questions: that professors valued women's classroom contributions less than men's (mean answer = 3.81, $p = 0.011$), but confirmed all other first year results.

Overall, it is likely that women have a slight feeling that their contributions to class are undervalued by professors. On the other hand, there is no evidence that women feel discriminated against in opportunity to contribute to class, nor that they feel that their contributions garner less respect from fellow students than men's do.

3.4. Is Computer Science too Male-Dominated?

We asked respondents about their perception of the male-female balance in computing compared to the balance they would prefer in their career field and found evidence that women think computing is more male-dominated than they would like. Specifically we asked:

"What is the distribution of men to women in computer-related careers?"

Women's mean = 3.16

"In your ideal career, what would the distribution of men and women be?"

Women's mean = 3.87

As in the previous questions, 4 represents a neutral value, in this case an even gender distribution. We reject the null hypothesis, that women think computing has an ideal balance of men and women ($p \approx 0$); our alternative hypothesis, that women think computing is more male-dominated than they would like, is supported. However, the women in this survey didn't see the field as much male-dominated as we expected, describing it closer to their ideal than we anticipated.

The follow up data generally supported these results, although with a slightly higher ideal balance (3.99) perceived by women.

3.5. Math Anxiety

To find out about the impact of math anxiety, we asked respondents to agree or disagree with the following statements:

"Mathematics plays a large role in computer science".

Women's mean = 5.29 Combined mean = 5.28

"I am comfortable solving mathematical problems".

Women's mean = 5.00 Men's mean = 5.01

Neither result suggests that math-anxiety plays an important role. We reject the null hypotheses for the first, that these answers are neutral (4.00), with $p \approx 0$ in each gender. The data supports our alternative hypotheses, that women alone, and men and women combined, recognize the importance of math to computer science. More importantly, men and women both agree that they are comfortable using math, with no statistically significant difference between them ($p = 0.94$). We therefore find no evidence that women leave our program because of math anxiety.

The follow up questionnaire produced similar results in all respects.

3.6. Does Computing Conflict with Family?

We asked how strongly respondents agree or disagree with the following statements:

"Computer scientists spend more time on work than on family".

Women's mean = 3.89

"Having time to raise my own family is a high priority for me".

Women's mean = 5.68 Men's mean = 5.42

This data does not suggest any significant difference. We cannot reject the null hypothesis for the first question—that women's mean answer should be 4.00 (i.e., "Indifferent") ($p = 0.227$). While both men and women felt that raising a family was important, there was no statistically significant difference in their responses to the first question ($p = 0.147$). We thus find no reason to believe that women leave our computer science program because they think a career in computer science conflicts with raising a family.

The follow up results were similar, except that women do disagree to a weak but statistically significant extent with the statement that computer scientists spend more time on work than on family (mean answer = 3.75, $p = 0.011$).

4. Conclusions and Recommendations

Our results must be interpreted with care. The population we studied was restricted to students in introductory computer science courses at SUNY Geneseo. The barriers we studied may operate more strongly on students who never take any computer science, on younger or older students, or on students in other schools. Furthermore, we didn't test all of the barriers suggested in the literature. Nonetheless, we do believe that we can reach some interesting conclusions:

- Of the six barriers explored, the results from only two—self confidence and male dominance—yielded significant differences that might explain our inability to retain women within the field. And even for the two barriers to women detectable in our program, the evidence was fairly weak or mixed.

Far more significant (in both senses of the word: "interesting" and "statistically significant") were the backgrounds of women at the time they enter our introductory computing courses:

- women enter with far less computing experience than do men.

And most significant was the observation that:

- most women in our introductory courses never plan to major in computer science at all.

Put another way, the largest barriers to retaining women in computer science may be circumstances that occur long before they enter our programs. We did not identify the exact sources of these barriers: they may be systemic societal problems or may be caused by the early education process. But the simple observation remains: at the time women enter our program, they have had less experience with computing and do not intend to continue in the major.

One potential conclusion one could draw from these results is that we should throw up our hands and say "it isn't our problem!"—and we would not be the first to do so.

While a certain amount of recruitment can be done at the college level (e.g., through departmental publicity, campus poster sessions or other presentations, etc.), these results support the arguments that the roots of women's disinterest lie in childhood and even infancy [7]. A complete solution to such deep–seated problems may be beyond the reach of college computer science departments.

At Geneseo we prefer to think that this simply suggests that the problem is not one of retention as we thought it to be. Rather it is a problem of recruitment or outreach. The basic problem of retention of women into computer science may simply be getting women into the major in the first place. Even within the college environment, there are at least some steps that we can take:

- Outreach programs to school–age girls (e.g., summer "camps") can be conducted by college computer science departments, and seem to be quite effective in awakening girls' interest in computing [8, 9].
- At least in the U.S., undergraduate colleges are crucial training grounds for elementary and secondary teachers; computer science departments can work with schools of education to ensure that these teachers are suitable computer science role models for their students, and are prepared to accurately present the field to them.
- Mentoring programs, drawing on upper–level women students, women graduates, or women faculty as mentors for younger women, may reduce the background problems. Getting women into the major is the most important step, but we can't ignore the barriers that women face once there. Women's relative lack of pre–college computing experience is particularly significant, as it may hurt their performance in the first course relative to men [6]. This in turn can compound problems of flagging self–confidence. Departments should also raise faculty consciousness about working with less self–confident students and fairly valuing all students' opinions.

Our results should not be accepted without question yet. They need to be confirmed by broader–based studies at other schools. If such studies support our results (or even if they consistently produce different results), computer science will have an important guide to correcting its gender imbalance.

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